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Some information on testate amoebae of Iceland

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Abstract

In samples of mosses collected during an expedition in the year 1987 along the southern border of Iceland, in seven habitats on the slopes of Skerhöll Hill, south of the glacier Svínafellsjökull, 80 taxa of testate amoebae have been recorded. From these taxa 24 species are new to Iceland. Up to now, including our own data, on the basis of available sources 174 taxa have been reported for Iceland. In the mosses *Racomitrium heterostichum* and *Racomitrium fasciculare* an *Assulina muscorum – Centropyxis globulosa*-association has been recorded.

Key words: Testate amoebae – ecology – Iceland

Introduction

Probably the first record concerning testate amoebae from Iceland was published by RICHTERS (1905). His paper based on the study of Tardigrada on the eastern coast of the island in the arctic-alpine type vegetation communities rich in mosses. He recorded the occurrence of the following taxa in small numbers: *Arcella vulgaris* EHRENBERG, *Difflugia globulosa* DUJARDIN, *Centropyxis constricta* EHRENBERG, *Assulina seminulum* EHRENBERG, *Euglypha* sp. and *Nebela* sp.

VAN OYE studied the fauna of testate amoebae from the environs of Lake Thingvallavatn (VAN OYE 1939) and from a Sphagnetum near Krisuvik (VAN OYE 1940) during an expedition which included the research of several groups of invertebrates, algae and birds. Later, the research of testate amoebae in Iceland was continued by DECLOITRE (1965, 1966) and CHARDEZ (1969). For the different sampling sites of all these authors see Fig. 1.

During his expedition to Iceland in 1987, the late MSc. MICHAL FIALA from the Water Research Institute Brno collected samples of mosses and algae in seven habitats on the slopes of Skerhöll Hill, south of the glacier Svínafellsjökull (Fig. 1). The material was complemented by him by important data about the sampling sites.

These samples, together with the information about the sampling sites are the basis of the present study which gives an overview of testate amoebae and their ecology in seven habitats on the slopes of Skerhöll Hill, Iceland.

Material and Methods

Altogether 20 samples from 7 habitats were collected by MICHAL FIALA on July 13th, 1987. The samples predominantly contained mosses and blue-green algae. The material collected in aquatic environments was fixed in 4% formalin solution. Mosses collected outside of an aquatic environment were transported dry and moistened before treatment. Microscopic analysis was done using a Sedgwig-Rafter counting chamber, from each sample four chambers were analysed. The species determination

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was done after putting the sample on a slide with a micropipette and making permanent mounts. Species data were evaluated by the means of indices of dominance (D), frequency (F), and diversity (H′) according to Shannon and Weaver (Odum 1977). The classification was done by TWINSPAN (Hill 1979), and the results are shown in the form of a dendrogram.

The results were also evaluated by detrended correspondence analysis (DCA) (Ter Braak & Smilauer 1996). No samples and no species were omitted, that means: final number of samples = 20; final number of species = 80; number of occurrences = 344. No sample-weights were specified and rare species were down-weighted. The transformation of species data was done by the following equation:

$\ln(Ay + B) - A = 1.000$; $B = 1.000$.

The results of the evaluation by detrended correspondence analysis (DCA) are shown in the area of the 1st and 2nd ordination axis. Envelopes for groups of localities were constructed by the projection of the results of TWINSPAN analysis into the ordination space.

Description of sampling sites

The material was collected on Skerhöll Hill (503 m a.s.l.) lying below the Svínafellsjökull glacier in the west-southern part of the island within the range of Hvannadalshnúkur (with 2119 m a.s.l. the highest mountain in Iceland). The Svínafellsjökull glacier is the source of two streams, Hrútagil and Svarthamuragil. For the sampling area see Fig. 1.

The samples were collected from the peak of the hill westwards down along its slope.

The peak of the hill is rocky, and the sharp rocks are covered with mosses and lichens. The rocky zone in the lower parts passes into a zone of mosses followed by a zone of grasses. The rocks at the foothill were covered with moss.

In the following a description of the seven different habitats is given.

• Habitat A (503 m a.s.l.):
Peak of the hill covered with the moss *Racomitrium heterostichum* (Hedw.) Brid.
Air temperature: 15.0 °C.
– Sample No. 1.

• Habitat B (450 m a.s.l .):
Stones under scree cones covered with the moss *Racomitrium heterostichum* (Hedw.) Brid.
Air temperature: 15.0 °C.
– Sample No. 2.

• Habitat C (450 m a.s l.):
Heath through which a spring trickle flows. Its bottom and banks are covered with moss and lichen. The left bank is steep, up to 2 m high; the right low bank is covered with moss and lichen.

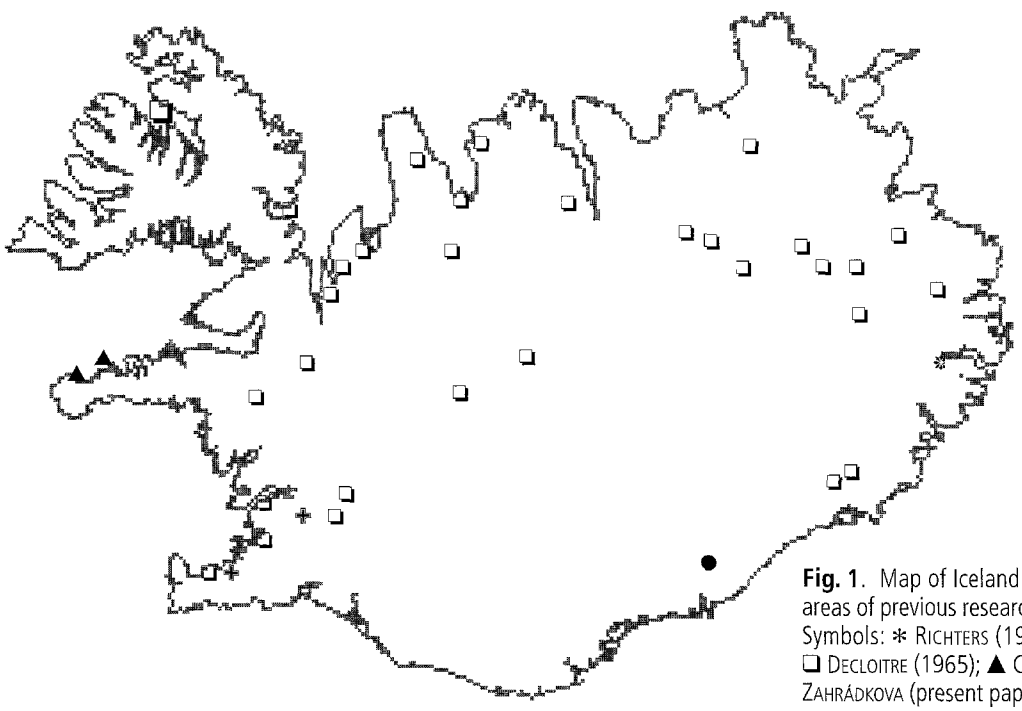

Fig. 1. Map of Iceland with sampling sites and study areas of previous research.
Symbols: * Richters (1905); + Van Oye (1939, 1940); ❑ Decloitre (1965); ▲ Chardez (1969); ● Opravilová & Zahrádkova (present paper).

Air temperature: 16.2 °C; water temperature: 9.8 °C.
- Sample No. 3: Moss *Bryum* sp. at the bottom near the bank.
- Sample No. 4: Moss *Bryum* sp. on the bank.
- Sample No. 5: moss (indet.) on the high low bank.
- Sample No. 6: *Sphagnum* sp. on the right low bank.

• Habitat D (360 m a.s.l.):
Heath in the lateral moraine.
Air temperature: 12.6 °C; water temperature: 10.4 °C.
- Sample No. 7: Free water.
- Samples No. 8 and 9: Mosses *Caliergonella cuspidata* (HEDW.) LOESKE and *Bryum* sp.
- Sample No. 10: Moss *Caliergonella cuspidata* (HEDW.) LOESKE.

• Habitat E (360 m a.s.l.):
Stream with strong flow discharging from the lateral moraine, stony bottom with rich growth of moss and blue-green algae.
Air temperature: 12.6 °C; water temperature 9.7 °C.
- Sample No. 11: Blue-green algae *Nostoc* sp.
- Sample No. 12: Moss *Drepanocladus* sp.
- Sample No. 13: Moss *Hygrohypnum* sp.
- Sample No. 14: Blue-green algae *Nostoc* sp.

• Habitat F (140 m a.s.l.):
Stream with low flow and rich growth of blue-green algae and algae discharging under the frontal moraine at the easternmost margin of Svínafellsjökull glacier.
Air temperature: 12.5 °C; water temperature: 10.4 °C.
- Sample No. 15: Moss *Hygroamblystegium tenax* (HEDW.) JENN.
- Sample No. 16: Moss *Caliergonella cuspidata* (HEDW.) LOESKE
- Sample No. 17: Moss *Caliergonella cuspidata* (HEDW.) LOESKE
- Sample No. 18: Not identifiable fragments of moss stalks.
- Sample No. 19: Moss *Racomitrium fasciculare* (HEDW.) BRID.

• Habitat G (140 m a.s.l.):
At the foot of the hill, near the village of Svínafell.
- Sample No. 20: Moss *Racomitrium heterostichum* (HEDW.) BRID.

Results and Discussion

In the samples from the seven habitats (A–G) altogether 80 taxa of testate amoebae have been recorded (Table 1). Therefrom, 24 taxa are new to the territory of Iceland (marked in Table 1 with an asterisk). This means that on

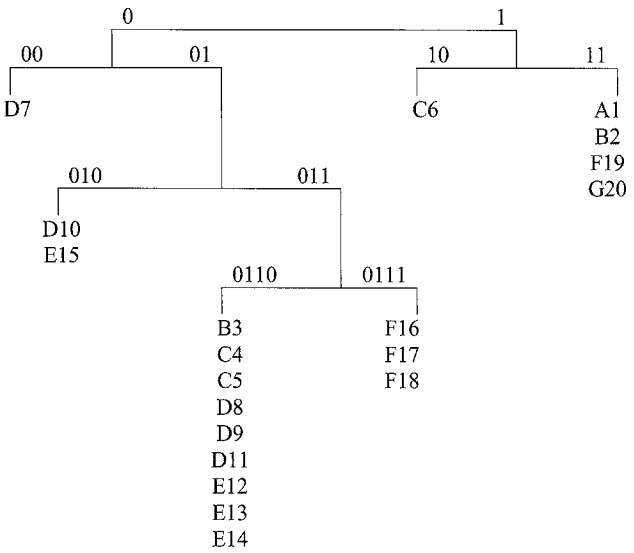

Fig. 2. TWINSPAN-dendrogram of the classification of samples.

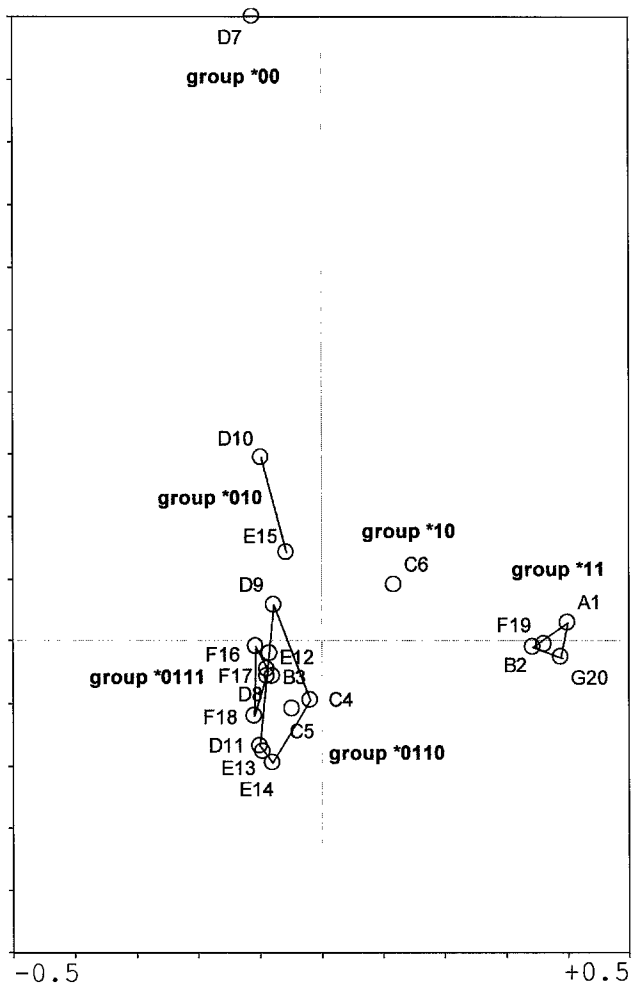

Fig. 3. Results of detrended correspondence analysis (DCA) of samples with projection of results of TWINSPAN classification (envelopes express clusters).

Table 1. List of taxa recorded in the seven habitats of Skerhöll Hill with dominance (%), frequency (%) and indices of species diversity (Shannon and Weaver). *: Taxa marked with an asterisks are new to the territory of Iceland.

	Dominance [%]																				Frequency [%]
Habitats	A	B	C				D				E				F					G	
No. of sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Taxon																					
Microchlamys patella Claparede & Lachmann			0.66							9.53		4.44			1.48	5.59					20
Arcella arenaria Greeff		0.55																		0.99	10
**Arcella arenaria sphagnicola* Deflandre							25.00														5
Arcella discoides Ehrenberg									1.72	4.76					0.50	5.59		0.88			25
**Arcella discoides foveosa* Playfair																	0.70	2.66			10
Centropyxis aculeata (Ehrenberg)			0.66									20.01			0.50	0.62	0.70				25
* *Centropyxis aculeata grandis* Deflandre															0.99						5
Centropyxis aculeata oblonga Deflandre			3.95	3.85	4.17	1.42		17.25	10.36		35.72	22.22	45.31	56.51	2.47	13.66	3.50	5.31			70
Centropyxis aerophila Deflandre		2.22																	16.48	2.97	15
Centropyxis aerophila sphagnicola Deflandre		1.31							0.86								0.70		1.14		20
Centropyxis cassis Deflandre			1.97	3.85				1.72	4.32				1.56				0.70				30
Centropyxis constricta (Ehrenberg)			0.66																		5
Centropyxis ecornis (Ehrenberg)	0.99																				5
Centropyxis globulosa Bonnet & Thomas	11.32	0.55																	1.14	33.66	20
Centropyxis minuta Deflandre			0.66		4.17								1.56								15
Centropyxis platystoma (Penard)			1.97									8.89	1.56	4.35		1.87	1.40				30
Centropyxis sylvatica Deflandre	0.59	2.79	10.53	15.38	25.00	1.90		6.90	7.76	4.76	7.14	6.67	6.26	13.04	9.41	5.59	4.90				80
Cyclopyxis arcelloides (Penard)																0.62					5
Cyclopyxis eurystoma Deflandre	8.93	14.44		3.85					1.72										6.82	20.79	30
* *Cyclopyxis eurystoma parvula* Bonnet & Thomas		0.55	1.97		4.17			1.72													20
Cyclopyxis kahli Deflandre		0.55	0.66					1.72													15
* *Trigonopyxis arcula* (Leidy)					4.17																5
Plagiopyxis callida Penard	1.79																				5
**Plagiopyxis declivis* Bonnet & Thomas				11.53		0.95			1.72			2.22								0.99	25
**Plagiopyxis labiata* Penard	1.19	1.67																			10
Difflugia acuminata Ehrenberg															0.50	0.62					10
Difflugia avellana Penard																	0.70				5
* *Difflugia brevicolla* Cash & Hopkinson															0.50						5
Difflugia bryophila Penard								3.45							0.99	0.62					15
* *Difflugia difficilis* Thomas																		0.88			5
* *Difflugia difficilis ecornis* Chardez		0.55	3.95	7.69				1.72	0.86		7.14		3.12				0.70				40
* *Difflugia dujardini* Chardez			2.63		16.67				3.45						0.99		0.70				25
Difflugia elegans Penard									0.86								1.40				10
* *Difflugia fallax* Penard									0.86							0.62	1.40	2.66			20
Difflugia globulosa Dujardin			3.29	3.85				5.17	0.86				7.82				0.70	3.54			35
Difflugia lanceolata Penard															0.50						5

* *Difflugia linearis* PENARD			1.31						4.76											10
Difflugia lucida PENARD			0.66					0.86												10
Difflugia penardi CASH & HOPKINSON			2.63																	5
Difflugia pulex PENARD			1.31																	5
Difflugia pyriformis PERTY							1.72	0.86	4.76	7.14	2.22	1.56		4.95	1.87	1.40	2.66			50
**Difflugia rubescens* PENARD							1.72	1.72	4.76			3.12			0.62	0.7				30
Heleopera petricola LEIDY													4.35							5
Heleopera rosea PENARD						1.42		1.72						2.47						15
Heleopera sylvatica PENARD			1.31														1.77			10
Hyalosphenia elegans (LEIDY)							1.72	0.86						1.48						15
Nebela bohemica TARÁNEK		1.67	0.66			38.39								1.48						20
Nebela collaris (EHRENBERG)		0.66						0.86			2.22			1.98		0.70	0.88			30
Nebela dentistoma PENARD			5.27					4.32	14.29			3.12		14.36	0.62	0.70				35
Nebela lageniformis PENARD	0.59					0.47	25.00	0.86	4.76					1.98						25
Nebela tubulosa PENARD								0.86												5
**Paraquadrula irregularis* (ARCHER)								3.45						1.48	3.11	5.59				20
Quadrulella symmetrica (WALLICH)			9.21	3.85	8.32	0.47		3.45	4.76		4.44			13.37	1.24					45
Quadrulella symmetrica longicollis (TARÁNEK)								0.86				1.56								10
Phryganella acropodia (HERTWIG & LESSER)																	0.88			5
* *Phryganella nidulus* PENARD															1.24	0.70	6.20			15
* *Difflugiella splendida* SCHÖNBORN			5.27				50.00	36.21	19.83		6.67				14.29	15.38	4.43			40
Assulina muscorum GREEFF	52.98	28.89			4.17	2.37								0.50		0.70		34.09	23.77	40
Corythion dubium TARÁNEK	12.50	21.67				8.06								0.50				9.09	7.92	30
* *Corythion dubium terricola* SCHÖNBORN																			1.98	5
Euglypha acanthophora EHRENBERG			0.66	3.85	8.32	2.84		3.45					4.35		8.07	8.39	3.54			15
Euglypha acanthophora flexuosa PENARD															2.48	2.09	0.88			15
Euglypha ciliata (EHRENBERG)														0.50	0.62	0.70	0.56			20
Euglypha cristata LEIDY								0.86	4.76					1.98						15
Euglypha filifera PENARD						8.53								2.47		0.70	0.88			20
Euglypha laevis PERTY	1.79	3.33	5.92	7.69		4.74		5.18	1.72	4.76		6.67	4.69	8.70	5.94	0.62	1.40	0.88	4.54	4.95	85
Euglypha strigosa glabra WAILES	7.14	16.67																	13.64		15
Sphenoderia lenta SCHLUMBERGER								1.72	4.76					1.47						15
Tracheleuglypha dentata (PENARD)			1.31	3.85		0.47		5.18												20
Trinema complanatum PENARD	0.59	2.79				5.69													7.39	0.99	20
Trinema enchelys (EHRENBERG)														0.99		0.70	0.88			15
Trinema lineare PENARD	0.59	1.11	14.48	30.76	4.17	22.28		3.45	3.45	4.76	7.14	8.89			20.30	6.83	9.79	9.75	5.11	0.99	85
* *Campascus minutus* PENARD			3.95					3.45	2.59			4.44	3.12				0.70				30
Cyphoderia ampulla (EHRENBERG)			1.97		4.17				1.72	19.06						0.62	0.70	0.88			35
* *Cyphoderia ampulla crassa* (HUSNOT) THOMAS																	0.70				5
* *Chlamydophrys stercorea* CIENKOWSKI														3.11				13.28			10
Pseudodifflugia archeri ?									4.76								4.19				10
* *Pseudodifflugia globulosa* ŠTĚPÁNEK			2.63					3.45	2.59		35.72		6.26	8.70	1.98	19.26	19.58	32.74			50
* *Pseudodifflugia gracilis* SCHLUMBERGER			5.92		12.50			3.45					9.38				6.29	3.54			30
* *Pseudodifflugia gracilis terricola* BONNET & THOMAS								0.86													5
Index of diversity H'	**1.57**	**2.00**	**3.06**	**2.17**	**2.25**	**1.93**	**2.30**	**2.23**	**3.08**	**2.56**	**1.49**	**1.04**	**2.03**	**1.42**	**2.75**	**2.62**	**2.82**	**2.42**	**1.95**	**1.75**	

the basis of the available sources – including our own data – 174 taxa of testate amoebae have been reported for Iceland.

In the aerophytic mosses *Racomitrium heterostichum* and *Racomitrium fasciculare* which covered stones both on the top and at the foot of Skerhöll Hill an association was found in which the species *Assulina muscorum* (samples No. 1, 2, 19 and 20) reached high abundance. The species *Centropyxis globulosa* occurred merely in these four samples. *Assulina muscorum* and *Centropyxis globulosa* were accompanied by other rather abundant species: *Centropyxis aerophila, Cyclopyxis eurystoma, Corythion dubium* and *Euglypha strigosa glabra.* The four samples No. 1, 2, 19 and 20 clearly differed from the other ones, with the exception of sample No. 6. According to TWINSPAN classification the indicator species of this group of samples (Nos. 1, 2, 6, 19 and 20) was *Trinema complanatum.*

These results are also shown in the TWINSPAN–dendrogram given in Fig. 2. The right side of the dendrogram consists of two branches – group No. 10 (with sample No. 6 exclusively) and group 11 (with the four samples No. 1, 2, 19 and 20). From the projection of the TWINSPAN classification into an ordination diagram (Fig. 3) the location of group No. 11 at the right side of the diagram and the location of sample No. 6 (group 10) nearer to the central part of the diagram is visible.

Drier *Sphagnum* (sample No. 6) presented the transition between aerophytic and aquatic habitats, where the species *Nebela bohemica* (D = 38.39%) dominated and where both aquatic species (e.g. *Euglypha filifera*), and species from dry habitats (e.g. *Corythion dubium)* were present.

The association characterised by the occurrence of *Assulina muscorum* and other accompanying species can be assumed to be typical of lichens and aerophytic mosses of the Arctic and Subarctic regions. BEYENS et al. (1986) mention the *Assulina muscorum*-association from the driest habitats of Greenland, Jan Mayen Island and the Spitsbergen Islands. The *Centropyxis aerophila*- and *Corythion dubium*-associations were mentioned by these authors from more moist habitats. Research on testate amoebae of the Shetlands and the Faeröer Islands showed that the association of *Assulina muscorum* and *Euglypha strigosa glabra* prevails the driest habitats (lichens, mosses) (BEYENS et al. 1988). OPRAVILOVÁ (1989) found a rich occurrence of *Assulina muscorum* in one specimen of liverworts (*Scapania* sp.) in samples from Spitsbergen. However, also a mass occurrence of *Plagiopyxis labiata* was recorded. Two other species, i.e. *Euglypha strigosa glabra* and *Pseudodifflugia gracilis terricola*, were very numerous. According to HARNISCH (1927, 1939) all above mentioned taxa are members of the community of "Waldmoos type", which represents dry habitats of bog margins or dry forest mosses.

In Germany, JUNG (1936) studied the species *Assulina muscorum*, which reaches its maximum development especially in bogs. With regard to the fact, that mosses and lichens predominate in the moss tundra vegetation cover in the Arctic and Subarctic regions, the associations of the species *Assulina muscorum* are more widespread there than in Central Europe, where they are mainly limited to marginal parts of bogs and where they create small tussocks with xerophytic vegetation.

The samples from aquatic habitats (Nos. 3–5 and Nos. 7–18) formed a more or less comparatively compact group. The most frequent species were *Centropyxis aculeata oblonga* (F = 70%), *Centropyxis sylvatica* (F = 80%), *Euglypha laevis* (F = 85%) and *Trinema lineare* (F = 85%).

Table 2. Dominance (in %) of families of testate amoebae: a comparison of five different information sources.

Family	VAN OYE (1939)	VAN OYE (1940)	DECLOITRE (1965)	CHARDEZ (1969)	OPRAVILOVÁ & ZAHRÁDKOVÁ (this paper)
Microcoryciidae				1.28	1.27
Arcellidae	14.29	14.82	11.19	11.54	5.02
Centropyxidae	9.52	3.70	18.66	10.26	21.27
Plagiopyxidae				2.56	3.77
Difflugiidae	19.05	3.70	12.69	12.82	22.27
Nebelidae	9.52	22.22	17.91	17.96	15.03
Phryganellidae			1.49	2.56	2.53
Cryptodifflugiidae			0.75	2.56	1.27
Euglyphidae	42.86	51.86	33.58	33.33	17.53
Cyphoderiidae	4.76	3.70	1.49	3.85	3.77
Paulinellidae			1.49		
Gromiidae			0.75		6.27
Amphistomidae				1.28	

Only sample No. 7 from free bog water, in which only three taxa were found, showed different diversity and differed from the other samples (e.g. Fig. 3) by the presence of the species *Arcella arenaria sphagnicola.*

Samples No. 16-18 from habitat F formed a subgroup characterised by the presence of the species *Phryganella nidulus* and *Euglypha acanthophora flexuosa.*

From the species not found in Iceland or in other Arctic and Subarctic regions before (BEYENS et al. 1988; OPRAVILOVÁ 1989; BEYENS et al. 1991; BALÍK 1994), *Phryganella nidulus* and *Difflugiella splendida* should be mentioned. The species *Phryganella nidulus* occurred only in the moss *Caliergonella cuspidata* (habitat F). The species *Difflugiella splendida,* which was described from the periphyton on *Typha* sp. from the Mazurian lakes in Poland (SCHÖNBORN 1965), occurred in our material quite often (F = 40%), most frequently in the moss *Caliergonella cuspidata.* In total, 107 individuals of this species were found, most of them (89) containing green ball-shaped algae in their cytoplasm.

On the contrary, the species *Paraquadrula irregularis,* which was scarce in our material, was shown to be one of the three most abundant species – apart from *Centropyxis aerophila* and *Paraquadrula penardiana* – in Devon Island, Canada by BEYENS et al. (1991).

A comparison of the species diversity values (H') shows that the colonisation of aquatic habitats was richer than that of aerophytic habitats (Table 1).

Among the families of testate amoebae found by VAN OYE (1939, 1940), DECLOITRE (1965) and CHARDEZ (1969) in Iceland, the family Euglyphidae was the most numerous. However, in our material Euglyphidae ranked third while Difflugiidae ranked first and Centropyxidae second (see Table 2). We assume that this difference can be explained by the fact that our material originated from a restricted area, while the 150 samples studied by DECLOITRE and the 191 samples studied by CHARDEZ came from a number of sites in different parts of Iceland.

Comparing the fauna of testate amoebae from North America and Northern Europe, DECLOITRE (1965) came to the conclusion that the Icelandic fauna of testate amoebae is part of the North-European fauna and that it is closer connected with the European fauna than with that of North America.

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